Developed to comply with Blu-ray standards for next generation DVD storage and video applications, Sharp's demonstration of the world's first MBE produced violet laser diode raises a number of interesting issues.

Gail Purvis

MBE springs blue-violet laser diodes

"There are still design issues on LEDs and laser diodes that are not going to be solved overnight," says Dr Jon Heffernan, manager of the Advanced Optoelectronic Devices Group at Sharp Laboratories of Europe in Oxford.

It is his team of five who have produced the first blue-violet emitters in the 400-405nm (violet) and 415-420nm (blue) wavelengths, based on nitride semiconductors grown by MBE.

"Sharp," points out Dr Heffernan "produces a major share of the red laser market for applications such as DVD at its Mihara plant in Japan, where it uses GaInP devices grown and mass produced by MBE."

The attraction of MBE production for nitride based LEDs and LDs is clear from a manufacturing viewpoint. Advantages of MBE production include: reduced consumption of source materials, lower costs, less environmental impact (which Japanese players take seriously) and improved device reliability.

MBE, Heffernan points out, is a more accurate epitaxial technique, permitting more complex structures and much better control of layers at the atomic level, as well as a better control of the dopants.

Further, LED and LD suppliers (some 20 companies worldwide), such as Lumileds, Osram, Nichia and Cree, are using the MOCVD method for blue emitters. Taking an MBE approach, Sharp has unique, virgin IP expertise and could acquire more, without having to move into patent inhibited MOCVD.

"Ours is an R&D position currently," he says, adding that the lasers will require more work before the company will start to consider the commercial justification and implications of the results.

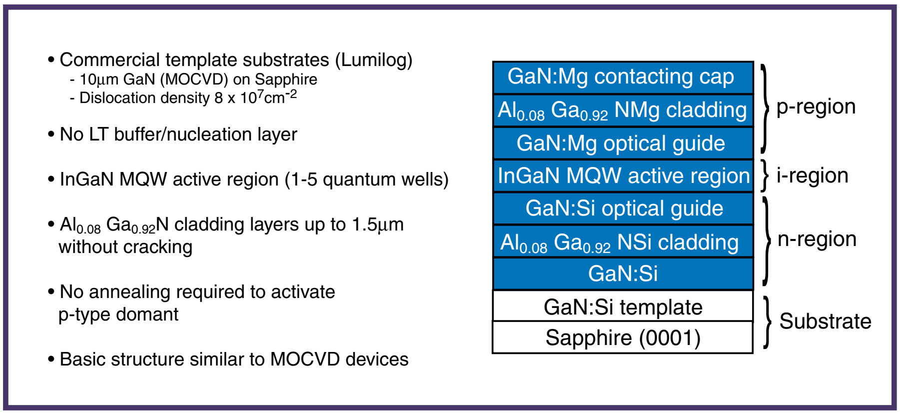

Figure 1. Blue-violet laser device structure grown by MBE at Sharp Laboratories of Europe

Sharp Laboratories' first demonstration blue-violet laser diode was grown on a template sapphire/GaN-Si substrate, providing low dislocation densities of $8x107cm^2$. Supplied by French start-up Lumilog, the substrate was produced by MBE. Devices were grown directly using a gas source VG Semicon (now Oxford Instruments Plasma Technology) V80 MBE reactor system, using NH^3 (group V) Ga, Al In (group III) Si (n type dopant) and CP_2Mg (p-type dopant).

The heart of the laser diode structure (Figure 1) is the InGaN quantum well active region of between 1-5 QWs, currently using 3. Optical guides are on both sides of the i region, with p and n region cladding layers of AlGaN, achieving up to 1.5mm without earlier cracking problems.

Annealing is not required to activate the p-type dopant, notes Heffernan. MOCVD does not work with simple magnesium doping because of the material's hydrogen content. To achieve dopant activation, there has to be annealing outside the chamber, to drive hydrogen out of the layer thereby activating it. With MBE there is no hydrogen present, so no need for annealing to achieve activation.

The quality of the layers is not sufficient for commercial performance as yet. "With InGaN there has not been an understanding of the details and for QWs this is very important," says Heffernan. "With the MQW active region, we look at the LED first to improve the power output. Working in collaboration with Professor Colin Humphrey's group in Cambridge, with their TEM, we have also been able to improve the quality of layers. With a better understanding of the i-region we have been able to grow LDs with the threshold current density of $30KA/cm^2$ (1,5amps), which is quite good."

"Not high enough to be commercial," he concedes, "but very similar to the first MOCVD product performance to operate at room temperature." Future work will be the laser diode ridge waveguide and dry/wet etch micro facets. Facet coating and device package are critical issues. "Facet coating will have a big effect, but has not been evaluated yet," says Heffernan.

In a kingdom that has grown from the ingenious, if modest Ever-Sharp pencil, one suspects that no detail will be overlooked in Sharp's effort to make MBE the preferred manufacturing route for blue-violet laser diodes.